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CODED POLARIZATION-DEPENDENT ANALYZING

BACKGROUND OF THE INVENTION

The present invention relates to analyzing an optical signal transmitted through a device under test (DUT), in particular to analyzing an optical signal transmitted through a DUT located in a measurement arm of an interferometric measurement setup.

SUMMARY OF THE INVENTION

It is an object of the invention to provide improved analyzing an optical signal transmitted through a DUT. The object is solved by the independent claims.

When analyzing an optical signal transmitted through a DUT it can be advantageous to resolve polarization dependent information about polarization dependent properties of the DUT. Although this information is contained in the resulting signal, so far it requires repeated measurements to allocate this information to certain polarizations since there is only one signal leaving the DUT. An advantage of an embodiment of the present invention is the possibility of polarization dependent analyzing such an optical signal coming from the DUT.

Although signal parts having a certain polarization are superimposed it is possible to unambiguously separate the information in each signal part allocated to a certain polarization due to the present invention. This is made possible by making each signal part unique. Preferably, this can be done by coding each signal part. According to the present invention coding can be any type of coding as long as it is possible to identify each signal part by the used way of coding. E.g. coding could be done by any unambiguous coding scheme as known in the art, such as e.g. by modulating the signal (preferably with a pilot tone at a special frequency), and/or by applying a special code to the signal, etc.

For the purposes of the present invention it is not necessary to provide each signal with a coding, i.e. it is possible to let at least one of the signals uncoded.

The signals are preferably coded by intensity modulation of the signals, more preferably by using sinusoidal signals or binary codes.

The demodulation of the signal can be done by multiplying the signal with a corresponding sinusoidal signal of dedicated frequency or by multiplying the signal with each code. Due to the preferred orthogonality of the frequencies / codes it is then possible to allocate the thereby resolved information to a certain polarization.

In a first embodiment of the present invention the light emitted from a light source is split into at least two different light paths. Light in each arm is now coded. Afterwards the light is sent through at least two polarizers. Thus each polarization gets assigned a unique pilot tone frequency or code. At the output of the polarizer the light is combined again and sent through the DUT. A photo detector detects light leaving the DUT.

It is preferred and advantageous to modulate the light by orthogonal signals. For the case of using a pilot tone it is sufficient to modulate the signal by at least two different pilot frequencies. By using codes the codes are preferably orthogonal codes. This is preferred to resolve the information contained in the resulting signal and to avoid interference between the coded parts.

Due to the preferred embodiment of the invention it is possible to measure at least two polarizations simultaneously.

In a second embodiment of the present invention the DUT is located in a measurement arm of an interferometric measurement setup. It is possible to perform such interferometric measurements with an optical signal tuned in frequency or wavelength provided by a tunable laser source (TLS). Due to a preferred embodiment of the invention it is possible to make single sweep measurements in such setups and still gaining the polarization dependent information about the DUT.

Possible application fields of embodiments of the present invention are all measurement setups for measuring an optical property of a device under test using a TLS.

Other preferred embodiments are shown by the dependent claims.

It is clear that the invention can be partly embodied or supported by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Features that are substantially or functionally equal or similar will be referred to with the same reference sign(s).

Fig. 1, 2 and 3 show schematic illustrations of embodiments of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now in greater detail to the drawings, Fig. 1 shows a schematic illustration of a first embodiment of the present invention. According to this embodiment an optical signal 6 of a TLS 4 is provided to a first coupler 105. The first coupler 105 has 4 output ports and splits the optical signal 6 into 4 parts 6a, 6b, 6c and 6d. Each signal part 6a, 6b, 6c and 6d is modulated by modulators 27, 29, 127 and 129, respectively. The first signal 6a is modulated using a first binary code code 1, the second signal part is modulated using a second binary code code 2, the third signal part is modulated using a third binary code code 3, and the fourth signal part is modulated using a fourth binary code code 4. Codes 1, 2, 3 and 4 are orthogonal to each other.

Subsequently each coded signal 6a′, 6b′, 6c′, 6d′ receives a defined polarization by polarization controllers 27a, 29b, 127c, 129d in the path of the coded signal 6a′, 6b′, 6c′, 6d′, respectively. The resulting polarized signals 6a′′, 6b′′, 6c′′, 6d′′ are then combined at a coupler 135 and provided as a superimposed signal 136 to a DUT 10. As modulators 27, 29, 127, 129 intensity modulators (e.g. $LiNbO_3$– based) can be used.

A signal 140 leaving the DUT 10 is then detected at a detector 44. A detector signal 48 containing coded signals for main polarizations and cross polarization is then provided to a correlation unit 52 containing four correlators 52-1, 52-2, 52-3 and 52-4. Each

correlator 52-1, 52-2, 52-3 and 52-4 is demodulating the signal 48 by multiplying signal 48 with the codes code 1, code 2, code 3 and code 4, respectively. The results of the demodulation is then provided by the correlation unit 52 at output ports a, b, c and d of the correlators 52-1, 52-2, 52-3 and 52-4, respectively.

Figure 2 shows a second embodiment of the present invention. It comprises an interferometer 2. Interferometer 2 comprises a TLS 4 providing an optical signal 6 to a first coupler 5 connected to a measurement arm 8, containing a DUT 10, and to a reference arm 12. Measurement arm 8 comprises a polarization beam splitter (PBS) 14 located before the DUT 10 splitting a measurement signal 18 into a first part 16 having a first polarization and a second part 20 having a second polarization orthogonal to the first polarization. The first part 16 is modulated by a modulator 27 with a first binary code (code 1) indicated by an arrow 17 and the second part is modulated by a modulator 29 with a second binary code (code 2) indicated by an arrow 19. Then at coupler 30 both parts are combined and provided to the DUT 10. As modulators 27, 29 intensity modulators (e.g. $LiNbO_3$-based) are used here.

A signal 32 leaving the DUT 10 is then superimposed at a coupler 35 with a reference signal 34 of reference arm 12 to a superimposed signal 36. Subsequently the superimposed signal 36 is orthogonal split by a second PBS 38 into two orthogonal parts 40 and 42, the polarization of which is indicated by arrows 41 and 43, respectively. Parts 40 and 42 are provided to detectors 44 and 46. The signals 40 and 42 at each detector 44 and 46 contain both the information about the first polarization, e.g. the main polarization, and the second polarization, e.g. the cross polarization. The detector signals 48 and 50 are provided to a correlation unit 52 containing four correlators 52-1, 52-2, 52-3, and 52-4. Each correlator 52-1, 52-2, 52-3, and 52-4 is demodulating the signals 48 and 50, respectively, by multiplying each signal with the respective codes 17 or 19 as indicated by the circles containing crosses in Fig. 1. The result of the demodulation is then provided at output ports a-d of the correlators 52-1 to 52-4.

Fig. 3 shows a schematic illustration of another embodiment of the present invention. According to this embodiment, the reference arm 12 contains a delay line 60 providing a delay $\Delta\tau$ to the reference signal 34. For further details of the construction and the

function of the delay line 60, it is referred to the parallel International patent application No. PCT/EP02/07726 of the applicant, the disclosure of which is incorporated herein by reference.

Furthermore, after the delay line 60, there is integrated in the reference arm 12 a third modulator 62, which is prepared to apply a reference code (code ref) to the reference signal 34. Contrary to the embodiment of Fig. 1, there is provided a coupler 64 to split the resulting superimposed signal 36 into a first part 36a and a second part 36b before being split by PBS 38. The second part 36b is then provided to a third detector 66 that provides a signal 68 to a fifth correlator 70. Correlator 70 identifies a part of the superimposed resulting signal 36 corresponding to the reference signal 34 by multiplying the second part 36b of the reference signal 36 with the reference code ref. In order to separate the signals it is required that code 1 and code 2 are orthogonal and code 1 and code ref are non-orthogonal and code 2 and code ref are also non-orthogonal.

Since delay line 60 provides a periodic delay $\Delta\tau$ to the reference signal 34, it is possible to analyze DUTs 10 with large delays.

The result of the interferometric analysis according to the embodiments illustrated in Figs. 2 and 3 is provided for each state of polarization provided by PBS 14 at outputs a-d of the respective correlators 52-1 to 52-4. Accordingly, a wavelength reference signal is unambiguously provided at output e of correlator 70.